Remarks/Arguments

The examiner is thanked for thoroughly reviewing the subject patent application. Applicants wish to point out the major features of their claimed invention, which is a CPP (current perpendicular to plane) GMR magnetic sensor in which a laminated magnetically free layer provides an advantageous combination of low coercivity and small positive coefficient of magnetostriction.

Prior art CPP GMR sensors have incorporated free layers of FeCo (denoting $Fe_{50}Co_{50}$) that are used alone or grown on a Cu layer (FeCo/Cu). Such a free layer has certain advantageous properties, yet it has other properties that make it undesirable for free layer use. For example, FeCo has larger bulk and interface spin asymmetry parameters than a CoFe layer (i.e., $Co_{90}Fe_{10}$, an alternative prior art choice for a magnetically free layer), which is advantageous. On the other hand, FeCo has a high coercivity and a large positive magnetostriction, both of which are distinctly disadvantageous in a free layer. CoFe by itself or when grown on a Cu layer (CoFe/Cu), on the other hand, has a low coercivity, which is distinctly advantageous in a free layer, yet it also has a large negative magnetostriction, whose coefficient is in the range between -10^{-6} to -10^{-7}, which is disadvantageous.

The objects of the present claimed invention (see claims 1 and 12) are realized by forming a free layer as a multiply laminated structure comprising thin lamina of FeCo, having thicknesses between approximately 2.5 and 7.5 angstroms, interspersed with thicker layers of CoFe, having thicknesses between approximately 7.5 and 15 angstroms and also including Cu spacer layers formed on the CoFe layers, the Cu layers having

thicknesses between approximately 1 and 4 angstroms. These laminated structures will retain the low coercivity of the CoFe, introduce the advantageous spin asymmetry of the FeCo, while bringing magnetostriction values within the acceptable small positive limits between 10^{-7} and 10^{-6} by combining the large positive magnetostriction values of the FeCo with the large negative magnetostriction values of the CoFe. In addition, the bulk and interface properties of the FeCo enhance the overall bulk scattering coefficient of the laminated free layer, thereby enhancing the CPP GMR ratio. Moreover, the arrangement and multiplicity of the very thin FeCo lamina make it possible to fine-tune the coercivity and magnetostriction of the free layer, which is distinctly advantageous for the fabrication of a variety of devices.

An additional aspect of the invention is the inclusion of multiple laminations of FeCo/Cu bilayers within the ferromagnetic layer of the synthetic pinned layer that is contiguous with the Cu spacer layer (see claim 11 of the Application). The FeCo used in these laminations are not the thin lamina used within the free layer, but are formed to a thickness between approximately 7.5 and 15 angstroms. It is found that the combination of the laminated free layer and the laminated pinned layer produce a GMR sensor that is significantly improved over those of the prior art.

Having thus briefly explained the present claimed invention, Applicants would like to respectfully address the specific comments, objections and rejections as presented and numbered by the Patent Examiner.

Examiner's Comments

1. Examiner correctly notes that the Application contains two claims numbered "4". Accordingly, Applicants have retained the number "4" for the first claim 4 (called "4a" by Examiner) and the second claim "4" (called "4b" by Examiner) has been canceled, along with claims 3, 5-7 and 14-19. This renumbering leaves remaining claims 8-13 and 20-23 with their original numbering unchanged.

2. References to "improved" qualities in the preambles of independent claims 1 and 12 (Examiner's claim 13) have been removed.

Claim Objections

3. Claim 23 (renumbered "24" by Examiner) incorrectly referred to "the sensor of claim 7," it should have referred to "the method of claim 12" and it has been amended to recite that dependency. Therefore, Examiner's renumbered claims 24 and 12, that were substantially identical in the Application, should not have been identical. Claim 23 (Examiner's claim 24) belongs with the method claims while claim 11 (Examiner's "12") belongs with the device claims.

4. Claims 8-11 (Examiner's claims 9-12) and claims 20-23 (Examiner's claims 21-24) are objected to as being dependent upon a rejected base claim (claims 1 and 12 respectively). Some of the limitations of claims 8-11 have been included within amended

claim 1 and some of the limitations of claims 20-23 have been included within amended claim 12. This will be discussed below.

Claim Rejections-35 USC 112

6. Claims 1 and 12 (Examiner's claim 13) have been amended to remove the term "ultra-thin." Claims 2 and 13 (Examiner's claim 14) have been amended to remove the term "iron rich."

Claim Rejections- 35 USC 103

8. Applicants respectfully request reconsideration of the rejections of amended claim 1 and amended claim 12 as being unpatentable over Gill (US Patent No. 6,127,045) in view of Smith et al. (US Patent App. No. 2002/0085323 A1) for the following reasons.

Gill describes an MTJ (or TMR) (magnetic tunnel junction or tunneling magnetoresistive) device in which a high spin polarization ferromagnetic sublayer of $Ni_{40}Fe_{60}$, having an enhanced magnetoresistive effect but undesirable positive magnetoresistive coefficient, has a negative magnetostriction sublayer of $Ni_{90}Fe_{10}$ placed adjacent to it in order to yield an overall negative magnetostriction coefficient (column 3, lines 43-46 and column 5, lines 58-60). Gill further describes, within the same invention, an antiferromagnetically coupled pinned layer in which a first ferromagnetic layer of positive magnetostriction coefficient is antiferromagnetically coupled to a second

ferromagnetic layer having a negative coefficient of magnetostriction (column 6, lines 34-41).

Unlike the present claimed invention, a CPP GMR device that includes multiply laminated free and pinned layers, the free layer formed of repeating structures comprising thin lamina of FeCo, having thicknesses between 2.5 and 7.5 angstroms, interspersed among thicker layers of CoFe, having thicknesses between 7.5 and 15 angstroms and also including Cu spacer layers between 1 and 4 angstroms in thickness formed between some of the CoFe layers, the MTJ device of Gill is described as having a free layer consisting of two sublayers, one having a thickness between 20 and 40 angstroms and the other being twice that thickness (Gill, column 5 lines 60-65 and column 6, lines 35-47). Furthermore, the present claimed invention discloses an antiferromagnetically coupled pinned layer in which one of the coupled layers (corresponding to Gill's first ferromagnetic layer) is laminated with layers of CoFe, FeCo and Cu spacer layers of different thicknesses than those within the free layer.

Applicants would further argue that their claimed invention, operating on the GMR principle rather than the MTJ principle and using many significantly thinner layers and lamina, thereby permitting extremely fine tuning of the sensor parameters, as is set forth in detail within the Specification of the Application, is not suggested by the combination of Gill and Smith.

With respect to the assertion that GMR and MTJ devices are in essence interchangeable, Examiner argues that "both sensors are functional equivalents and merely require the substitution of the spacer layer from an insulating material to a conductive material." While it is true that MTJ and GMR sensors differ in the nature of

the layer separating the free and pinned magnetic layers, this difference cannot be considered as a mere substitution. In fact, the two layers play entirely different physical roles within the context of their structures and it would have to be established by theory and experiment that merely substituting one for the other, in an otherwise similar sensor structure, would produce two forms of workable sensors. In the MTJ sensor, the thin insulating layer serves a quantum mechanical purpose of allowing electrons to tunnel through a classically impassible layer, from the free to the pinned layers, with a probability that depends on its thickness and the availability of electron states in the contiguous pinned layer. This is, therefore, a purely quantum mechanical phenomenon. In the GMR sensor, the conducting Cu spacer layer merely separates the free and pinned layers to reduce a magnetic interaction between them and, in itself, it serves no regulatory purpose as regards the flow of electrons. The flow of electrons through the Cu spacer layer is not determined by the Cu layer's thickness or by the available states in the pinned layer. It is, therefore, by no means evident or suggested by the inherent nature of the MTJ and GMR sensors that merely replacing a Cu layer by an insulating layer while maintaining the same free and pinned layers would thereby produce two different working sensor structures. Examiner seems to be relying on statements within the patent application of Smith et al. to conclude that the two types of sensors are functionally equivalent and interchangeable. Yet Smith states in his paragraph [0002] that "Physically distinct forms of magnetoresistance such as anisotropic magnetoresistance (AMR), giant magnetoresistance (GMR) and spin tunneling magnetoresistance (TMR) are well-known in the art." Note Smith's point that these forms are physically distinct. Examiner states (pg. 5) that "it is well known in the art that the only difference between a TMR and GMR

sensor is the selection of material for the spacer layer between the free and pinned layers (i.e. a GMR uses a metallic conductive layer and a TMR uses an insulating layer), as taught by Smith et al." Yet Smith claims at the very outset that these two sensor forms are physically distinct. Smith's invention pertains to the stabilization of the domain structure of a magnetic layer. That process is independent of whether the layer is operating in a GMR or TMR sensor, since in either case the magnetic layers should have stable domains. In the present claimed invention, the issue relates to the fundamental role and structure of the free and pinned layers in controlling electron flow within the sensor and, in that respect, Applicants would argue that the form of a free or pinned layer used in a TMJ sensor (eg. Gill) does not suggest the successful use of a similar free and pinned layer in a GMR sensor. Furthermore, Applicants would respectfully argue that, in any case, their free and pinned layers are patentably distinct from those of Gill because of the thickness and multiplicity of their layers, lamina and spacer layers as compared with the two sublayers described by Gill. Nevertheless, Applicants have amended their claims in light of Examiner's suggestion that claims 8-11 and 20-23 would be allowable if rewritten in independent form. The amended claims 1 and 12 presented herein now more clearly describe the invention by reciting the layer thicknesses and multiplicities in the multiply laminated free and pinned layers. Amended claims 1 and 12, however, do not incorporate the particular arrangement of layers and lamina in the preferred embodiment as recited in claims 8 and 20, but they do now recite the particular laminated structure of the free layer that render it distinct from that described by Gill.

In summation, Applicants wish to respectfully argue that their claimed invention is not suggested by the combination of Gill and Smith in light of the fact that Gill

describes a TMR device with a different free and pinned layer construction than the present claimed invention, while the invention of Smith does not suggest that mere replacement of a dielectric layer in a TMR device by a conducting layer will produce an operating GMR device.

Conclusion

The Examiner is thanked for thoroughly reviewing the application. All claims discussed above are now believed to be allowable. If the Examiner has any questions regarding the above application, please call the undersigned attorney at 845-452-5863

Respectfully submitted,

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